SECTION 230993
SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 SUMMARY

A. This Section includes control sequences for HVAC systems, subsystems, and equipment.

B. Related Sections include the following:

1. Division 23 Section "Instrumentation and Control for HVAC" for control equipment and devices and for submittal requirements.

1.3 DEFINITIONS

A. DDC: Direct digital control.

B. VAV: Variable air volume.

1.4 COOLING CONTROL SEQUENCES

A. Control Primary Circulating Pump(s):

1. Input Device: DDC system.
2. Output Device: DDC system command to starter relay.
3. Action: Energize pump(s) at occupied and unoccupied modes.
4. Initiate: Occupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: Binary output to motor starter (VFD).
   c. Action: Energize pump(s).
5. Initiate: Unoccupied Time Schedule:
   a. Input Device: DDC system demand.
   b. Output Device: Binary output to motor starter (VFD).
   c. Action: Energize pump(s).
6. Display:
   a. Outdoor-air temperature.
   b. Operating status of primary circulating pump(s).

B. Volume Flow Control:

a. Input Device: differential-pressure transmitter sensing differential pressure within the piping system.

b. Output Device: DDC system analog output to motor speed controller. Set variable-speed drive to minimum speed when pump is stopped.

c. Action: Maintain constant differential pressure within the piping system.

2. Display:
   a. Pump differential pressure indication.
   b. Pump differential pressure set point.
   c. Pump flow rate.
   d. Pump speed.

1.5 HEATING CONTROL SEQUENCES

A. Heating-Water Supply Temperature Control:
   1. Input Device: Temperature sensor.
   2. Output Device: Steam control valve.
   3. Action: Modulate steam control valve and flow rate to maintain heating-water supply temperature.
   4. Display:
      a. Heating-water supply temperature.
      b. Heating-water supply temperature set point.
      c. Steam control-valve position.

B. Heating-Water Supply Temperature Reset:
   1. Input Device: Outdoor-air temperature and enthalpy sensor.
   2. Output Device: DDC system software.
   3. Action: Reset heating-water supply temperature in straight-line relationship with outdoor-air temperature for the following conditions:
      a. 180 deg F heating water when outdoor-air temperature is below 32 deg F.
      b. 130 deg F heating water when outdoor-air temperature is 75 deg F.
      c. 100 deg F minimum, heating-water temperature.
   4. Display:
      a. Outdoor-air temperature.
      b. Heating-water supply temperature.
      c. Heating-water supply temperature set point.

C. Control Primary Circulating Pump(s):
   1. Input Device: DDC system.
   2. Output Device: DDC system command to starter relay.
   3. Action: Energize pump(s) at outdoor-air temperature below 75 deg F.
   4. Initiate: Occupied Time Schedule:
      a. Input Device: DDC system time schedule.

b. Output Device: Binary output to motor starter (VFD).

c. Action: Energize pump(s).

5. Initiate: Unoccupied Time Schedule:

a. Input Device: DDC system demand.

b. Output Device: Binary output to motor starter (VFD).

c. Action: Energize pump(s).

6. Display:

a. Outdoor-air temperature.

b. Operating status of primary circulating pump(s).

D. Volume Flow Control:

a. Input Device: differential-pressure transmitter sensing differential pressure within the piping system.

b. Output Device: DDC system analog output to motor speed controller. Set variable-speed drive to minimum speed when pump is stopped.

c. Action: Maintain constant differential pressure within the piping system.

2. Display:

a. Pump differential pressure indication.

b. Pump differential pressure set point.

c. Pump flow rate.

d. Pump speed.

1.6 DOMESTIC WATER HEATING CONTROL SEQUENCES

A. Domestic Water Heating Supply Temperature Control:

1. Input Device: Temperature sensor.

2. Output Device: Steam control valve.

3. Action: Modulate steam control valve to maintain domestic soft hot water supply temperature of 140 deg F.

4. Display:

a. Domestic soft hot water supply temperature.

b. Domestic soft hot water supply temperature set point.

c. Steam control-valve position.

B. Control Hot Water Recirculation Pump:

1. Input Device: DDC system.

2. Output Device: DDC system command to starter relay.

3. Action: Energize pump during occupied and unoccupied modes.

4. Initiate: Occupied Time Schedule:

a. Input Device: DDC system time schedule.

b. Output Device: Binary output to motor starter (VFD).

c. Action: Energize pump.

5. Initiate: Unoccupied Time Schedule:

a. Input Device: DDC system demand.

b. Output Device: Binary output to motor starter (VFD).

c. Action: Energize pump.

6. Display:

a. Operating status of primary circulating pump.

C. Volume Flow Control:

a. Input Device: Temperature sensor within the return piping system at the hot water recirculation pump.

b. Output Device: DDC system analog output to motor speed controller. Set variable-speed drive to minimum speed when pump is stopped.

c. Action: Maintain constant temperature within the piping system.

2. Display:

a. Domestic hot water recirculation temperature.

b. Domestic hot water recirculation temperature set point.

c. Pump flow rate.

d. Pump speed.

1.7 SOLAR WATER HEATING CONTROL SEQUENCES

A. COORDINATE WITH THE SOLAR DOMESTIC HOT WATER SYSTEM MANUFACTURER FOR EXACT SEQUENCE OF OPERATION FOR COMPLETE SYSTEM OPERATION INCLUDING SOLAR LOOP PUMPS, DOMESTIC WATER PUMPS, REQUIRED CONTROL VALVES, TEMPERATURE SENSORS, AND ACCESSORIES PER THE MANUFACTURERE'S RECOMMENDATIONS.

1.8 AIR-HANDLING-UNIT CONTROL SEQUENCES

A. Start and Stop Supply Fan(s):

1. Enable: Freeze Protection:

a. Input Device: Duct-mounted averaging element thermostat, located before supply fan.

b. Output Device: Hard wired through motor starter; DDC system alarm.

c. Action: Allow start if duct temperature is above 37 deg F; signal alarm if fan fails to start as commanded.

2. Enable: High-Temperature Protection:

a. Input Device: Duct-mounted thermostat, located in return air.

b. Output Device: Hard wired through motor starter; DDC system alarm.
c. Action: Allow start if duct temperature is below 300 deg F.

3. Initiate: Occupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: Binary output to motor starter.
   c. Action: Energize fan(s).
4. Initiate: Unoccupied Time Schedule:
   a. Input Device: DDC system demand.
   b. Output Device: Binary output to motor starter.
   c. Action: Energize fan(s).
5. Unoccupied Ventilation:
   a. Input Device: DDC system time schedule and output.
   b. Output Device: DDC system binary output to motor starter.
   c. Action: Cycle fan(s) during unoccupied periods.
6. Display: Supply-fan on-off indication.

B. Supply Fan(s) Variable-Volume Control:
1. Occupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: Binary output.
   c. Action: Enable control.
2. Volume Control:
   a. Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to conditioned-space static pressure.
   b. Output Device: DDC system analog output to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
   c. Action: Maintain constant supply-duct static pressure.
3. High Pressure:
   a. Input Device: Static-pressure transmitter sensing supply-duct static pressure referenced to static pressure outside the duct.
   b. Output Device: DDC system binary output to alarm panel.
   c. Action: Stop fan and signal alarm when static pressure rises above excessive-static-pressure set point.
4. Display:
   a. Supply-fan-discharge static-pressure indication.
   b. Supply-fan-discharge static-pressure set point.
   c. Supply-fan airflow rate.

d. Supply-fan speed.

C. Start and Stop Return Fan(s):

1. Initiate: Occupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: Binary output to motor starter.
   c. Action: Energize fans when supply fans are energized.
2. Initiate: Unoccupied Time Schedule:
   a. Input Device: DDC system demand.
   b. Output Device: Binary output to motor starter.
   c. Action: Energize fans when supply fans are energized.
3. Unoccupied Ventilation:
   a. Input Device: DDC system time schedule and output.
   b. Output Device: DDC system binary output to motor starter.
   c. Action: Cycle fan(s) during unoccupied periods.
4. Display: Return-fan on-off indication.

D. Return Fan(s) Variable-Volume Control:

1. Occupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: Binary output.
   c. Action: Enable control.
2. Volume Control:
   a. Input Device: Static-pressure transmitter sensing building static pressure referenced to outdoor static pressure.
   b. Output Device: DDC system analog output to motor speed controller. Set variable-speed drive to minimum speed when fan is stopped.
   c. Action: Maintain constant building static pressure.
3. Display:
   a. Return-air static-pressure indication.
   b. Return-air static-pressure set point.
   c. Return-fan airflow rate.
   d. Return-fan speed.
   e. Building static-pressure indication.
   f. Building static-pressure set point.

E. Preheat Coil:

1. Freeze Protection:
   a. Input Device: Unit-mounted averaging element thermostat, located after preheat coil.

b. Output Device: Hard wired through motor starter; DDC system alarm.

c. Action: Allow start if duct temperature is above 33 deg F.

2. Occupied Time Schedule:

a. Input Device: DDC system time schedule.

b. Output Device: Binary output to motor starter.

c. Action: Energize coil circulating pump(s).

3. Supply Air Temperature:

a. Input Device: DDC system time schedule and electronic temperature sensor.

b. Output Device: Modulating control valve.

c. Action: Maintain air temperature set point of 55 deg F.

4. Unoccupied Time Schedule:

a. Input Device: DDC system time schedule and outdoor-air temperature.

b. Output Device: Modulating control valve.

c. Action: Open coil heating water control valve when outdoor-air temperature falls below 35 deg F.

5. Display:

a. Preheat-coil air-temperature indication.

b. Preheat-coil air-temperature set point.

c. Preheat-coil control-valve position.

F. Mixed-Air Control:

1. Occupied Time Schedule:

a. Input Device: DDC system time schedule.

b. Output Device: DDC system output.

c. Action: Enable control.

2. Minimum Position:

a. Input Device: DDC system time schedule.

b. Output Device: DDC system analog output to modulating damper actuator(s).

c. Action: Open outdoor-air dampers to minimum position.

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3. CO2 Reset:

a. Input Device: CO2 space sensor connected to associated VAV box and air handling unit.

b. Output Device: DDC system analog output to modulating damper actuator(s).

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c. Action: When CO2 sensor reads a concentration below 1000 PPM (adjustable) the associated air handling unit outdoor-air damper shall modulate closed from its minimum position.

d. Action: When CO2 sensor reads a concentration above 1000 PPM (adjustable) the associated air handling unit outdoor-air damper shall modulate open until the CO2 concentration falls below 1000 PPM.

4. Heating Reset:
   a. Input Device: DDC system software.
   b. Output Device: DDC system analog output to modulating damper actuator(s).
   c. Action: Set outdoor-air dampers to minimum position.
5. Mixed-Air Temperature:
   a. Input Device: Electronic temperature sensor.
   b. Output Device: DDC system analog output to modulating damper actuator(s).
   c. Action: Modulate outdoor-, return-, and relief-air dampers to maintain air temperature set point of 55 deg F.
6. Cooling Reset:
   a. Input Device: Outdoor- and return-air, duct-mounted electronic temperature sensors.
   b. Output Device: DDC system analog to damper actuator(s).
   c. Action: Set outdoor-air dampers to minimum position when outdoor-air enthalpy exceeds return-air enthalpy.
7. Unoccupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: DDC system analog output to modulating damper actuator(s).
   c. Action: Position outdoor- and relief-air dampers closed and return-air dampers open.
8. Display:
   a. Mixed-air-temperature indication.
   b. Mixed-air-temperature set point.
   c. Mixed-air damper position.

G. Filters: During occupied periods, when fan is running, differential air-pressure transmitters exist.
1. Occupied Time Schedule:
   a. Input Device: DDC system time schedule.

b. Output Device: DDC system output.

c. Action: Enable control.

2. Differential Pressure:

a. Input Device: Differential-pressure switches.

b. Output Device: DDC system alarm.

c. Action: Signal alarm on low- and high-pressure conditions.

3. Display:

a. Filter air-pressure-drop indication.

b. Filter low-air-pressure set point.

c. Filter high-air-pressure set point.

H. Hydronic Heating Coil:

1. Occupied Time Schedule:

a. Input Device: DDC system time schedule.

b. Output Device: Binary output.

c. Action: Enable control.

2. Supply-Air Temperature:

a. Input Device: Electronic temperature sensor.

b. Output Device: Normally open modulating control valve.

c. Action: Maintain supply-air temperature set point of 55 deg F.

3. Temperature Reset:

a. Input Device: Electronic temperature sensor in return air.

b. Output Device: DDC system in straight-line relationship for the following conditions:

1) 65 deg F when return-air temperature is 70 deg F.

2) 55 deg F when return-air temperature is 75 deg F.

c. Action: Reset supply-air temperature set point of 55 deg F.

4. Temperature Reset:

a. Input Device: DDC system with input from room temperature sensors.

b. Output Device: DDC system.

c. Action: Reset supply-air temperature in response to greatest heating demand.

5. Unoccupied Time Schedule:

a. Input Device: DDC system time schedule and output.

b. Output Device: DDC system binary output.

c. Action: Return valve to normal position when fan is cycled on.

6. Display:

a. Fan-discharge air-temperature indication.

b. Fan-discharge air-temperature set point.
c. Heating-coil air-temperature indication.
d. Heating-coil air-temperature set point.
e. Heating-coil control-valve position.
f. Hot-deck air-temperature indication.
g. Hot-deck air-temperature set point.

I. Hydronic Cooling Coil:

1. Occupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: Binary output.
   c. Action: Enable control.
2. Supply-Air Temperature:
   a. Input Device: Electronic temperature sensor.
   b. Output Device: Normally closed modulating control valve.
   c. Action: Maintain supply-air temperature set point of 55 deg F.
3. Temperature Reset:
   a. Input Device: Electronic temperature sensor in return air.
   b. Output Device: DDC system in straight-line relationship for the following conditions:
      1) 65 deg F when return-air temperature is 70 deg F.
      2) 55 deg F when return-air temperature is 75 deg F.
   c. Action: Reset supply-air temperature set point of 55 deg F.
4. Temperature Reset:
   a. Input Device: DDC system with input from room temperature sensors.
   b. Output Device: DDC system.
   c. Action: Reset supply-air temperature in response to greatest heating demand.
5. Unoccupied Time Schedule:
   a. Input Device: DDC system time schedule.
   b. Output Device: Binary output.
   c. Action: Disable control.
6. Display:
   a. Fan-discharge air-temperature indication.
   b. Fan-discharge air-temperature set point.
   c. Cooling-coil air-temperature indication.
   d. Cooling-coil air-temperature set point.
   e. Cooling-coil control-valve position.

f. Cold-deck air-temperature indication.

g. Cold-deck air-temperature set point.

J. Coordination of Air-Handling Unit Sequences: Ensure that preheat, mixed-air, heating-coil, and cooling-coil controls have common inputs and do not overlap in function.

1.9 TERMINAL UNIT OPERATING SEQUENCE

A. Two-Pipe, Single-Coil, Fan-Coil, Unit:

1. Occupied Time Schedule:

a. Input Device: DDC system time schedule.

b. Output Device: Binary output.

c. Action: Start and stop fan and enable control.

2. Room Temperature:

a. Input Device: Electronic temperature sensor in room.

b. Output Device: Electronic control-valve operator.

c. Action: Modulate valve to maintain temperature.

3. Display:

a. DDC system graphic.

b. DDC system on-off indication.

c. DDC system occupied/unoccupied mode.

d. Room temperature indication.

e. Room temperature set point.

f. Control-valve position.

g. Supply-water temperature indication.

B. Four-Pipe, Hydronic Fan-Coil Unit:

1. Occupied Time Schedule:

a. Input Device: DDC system time schedule.

b. Output Device: Binary output.

c. Action: Start and stop fan, and enable control.

2. Room Temperature:

a. Input Device: Electronic temperature sensor.

b. Output Device: Electronic control-valve operators.

c. Action: Modulate multiport control valves to maintain temperature.

3. Display:

a. DDC system graphic.

b. DDC system on-off indication.

c. DDC system occupied/unoccupied mode.

d. Room temperature indication.

e. Room temperature set point.

f. Control-valve position.

C. VAV, Terminal Air Units with Hydronic Coils:

1. Occupancy:

a. Input Device: Utilize occupancy scheduled from associated air handling unit. Provide a space temperature sensor with occupancy override capabilities for changeover from unoccupied mode to occupied mode for a period of 2-hours when room occupancy override is activated.

b. Output Device: DDC system binary output.

c. Action: Report occupancy and enable occupied temperature set point.

1) Heating mode occupied temperature: 72 deg F.

2) Heating mode unoccupied temperature: 65 deg F.’

3) Cooling mode occupied temperature: 75 deg F.

4) Cooling mode unoccupied temperature: 82 deg F.

2. Room Temperature:

a. Input Device: Electronic temperature sensor with local override capabilities for temperature set point (similar to space sensors located within the existing facility).

b. Output Device: Electronic damper actuators and control-valve operators.

c. Action: Modulate damper and valve to maintain temperature.

1) Sequence damper from full open to minimum position, then valve from closed to fully open.

3. Display:

a. Room/area served.

b. Room occupied/unoccupied.

c. Room temperature indication.

d. Room temperature set point.

e. Room temperature set point, occupied.

f. Room temperature set point, unoccupied.

g. Air-damper position as percent open.

h. Control-valve position as percent open.

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D. Two-pipe, Chilled Water CRAC Unit with Humidification:

1. Occupied Time Schedule:

a. Input Device: DDC system time schedule.

b. Output Device: Binary output.

c. Action: Start and stop fan, and enable control.

2. Room Temperature/humidity:
   a. Input Device: Electronic temperature/humidity sensor.
   b. Output Device: Electronic control-valve, humidifier, and re-heat operators.
   c. Action: Modulate multiport control valves and electric reheat to maintain temperature. Modulate humidifier to maintain minimum humidity levels
3. Display:
   a. DDC system graphic.
   b. DDC system on-off indication.
   c. DDC system occupied/unoccupied mode.
   d. Room temperature indication.
   e. Room temperature set point.
   f. Room humidity indication.
   g. Room humidity set point.
   h. Control-valve position.
   i. Re-heat status.
   j. Humidifier status.

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PART 2 - PRODUCTS (Not Applicable)

PART 3 - EXECUTION (Not Applicable)

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